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EVALUATION OF TR-297/UQN-1 TRANSDUCER MODIFICATIONS.(U)
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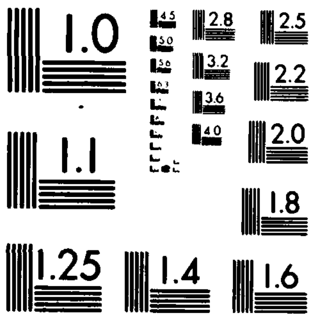

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Evaluation of TR-297/UQN-1 Transducer Modifications

ELMO W. THOMAS

Materials Section
Transducer Branch
Underwater Sound Reference Detachment
P. O. Box 8337, Orlando, FL 32856

February 8, 1980

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

Some proposed modifications to the TR-297/UQN-1 transducer have been investigated. The proposed changes are: replacement of silicone oil by castor oil, replacement of the rubber window with a copper-nickel window, and elimination of the internal pressure compensator. This report describes the test and evaluation of the transducer with these proposed changes and compares the measured performance to required performance specifications. The results indicate there is no measurable response differences between the silicone oil and castor oil and only a small degradation in performance with the substitution of the copper-nickel window. The pressure, internal to the transducer, stays within operational and safety limits without the pressure compensator.

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EVALUATION OF TR-297/UQN-1 TRANSDUCER MODIFICATIONS

INTRODUCTION

For many years, the fleet has been using model AT-200 transducers in the UQN-1 depth sounding system. These units were designed long ago on a high-priority procurement, without the benefit of modern research and enough development time. The original AT-200 models contained ammonium dihydrogen phosphate crystals, but through the years many modifications have been introduced. Ceramic elements have been substituted in a wide variety of geometric configurations. Approximately five years ago a new transducer (designated the TR-297) was designed by Dr. V. Salmon of Stanford Research Institute. This unit consists of a package of ceramic elements, pressure-release materials, transformers, and associated electronics designed to fit inside the old AT-200 cases. The build-up kits to perform this conversion were supplied to the Navy Shipyard Transducer Repair Facilities (TRFs) for assembly and testing and eventual installation in the fleet during the ships' dry dock cycles. Some testing has been done on the TR-297's by the TRFs and various civilian contractors [1]. Those tests revealed that in some areas the unit did not meet design specifications. Suggestions have been submitted by various activities to correct the deficiencies and/or to improve the original design. The TRFs requested that a replacement fill fluid be found for use instead of the silicone oil. NAVSEA Code 63XT requested a testing plan be initiated and conducted under the auspices of the Sonar Transducer Reliabilty Improvement Program (STRIP) [2] to determine the effectiveness of several proposed changes.

OBJECTIVE

The objective of the effort reported here was to determine the effects of silicone oil replacement by castor oil, rubber window replacement by a copper-nickel window, and elimination of the internal pressure compensator in the TR-297 transducers.

TEST PLAN

All measurements are to be conducted in accordance with the Compendium of Test Requirements and Operating Characteristics for NAVSEA Sonar Transducers (NAVSEA 0967-LP-410-2020).

Note: Manuscript submitted December 6, 1979.

1. Run two TR-297 transducers and compare the results to the published specifications. Replace the silicone oil with castor oil and repeat the measurements. Compare the two measurements and extract the differences.

2. Use two AT-200 transducers for acoustic evaluation of the copper-nickel window. Install a copper-nickel window on one transducer and a rubber window on the other. Measure the acoustic performance of both transducers in the parameters of interest. Exchange the windows between the two transducers and repeat the tests under identical conditions. Compare the measurements for degradation due to the differences in window material.

3. Subject a TR-297 with a copper-nickel window and no internal compensator to a temperature range of -60 to +75°C. Measure the deflection of the window as the thermally induced pressure increases. Compare these deflections to the plastic deformation limits for this type window material. During the process, observe if the integrity of all seals and components are maintained.

TEST RESULTS

1. Two TR-297 transducers were measured acoustically in the NRL-USRD Lake Facility at a temperature of 29°C and a depth of 4 m. After the measurements were completed, the silicone oil (Dow Corning DC 510,200 CS) was replaced with castor oil (Baker DB grade) and the measurements were repeated under identical conditions. The multiple measurements of both transducers were averaged for each type of oil, and the parameters are shown in Table 1.

Table 1 - Use of Castor Oil vs. Silicone Oil in TR-297 Transducer

Parameter	Unit	Specification	Castor Oil (Baker DB Grade)	Silicone Oil (Dow Corning DC 510,200 CS)
SPL	dB re 1 μPa/meter	$\geq$ +200	+204.3	+204.2
TVR	dB re 1 μPa/volt/meter	$\geq$ +154	+158.3	+158.2
FFVS	dB re 1 volt/μPa	$\geq$ -175	-172.2	-173.0

The differences between the responses of castor oil and silicone oil are smaller than the uncertainty of the measurement capability [3]. The test transducers respond equally well with castor oil and silicone oil.

2. Two AT-200 transducers were used to identify any acoustic performance differences between the copper-nickel window and the rubber window. One transducer had a copper-nickel window while the other had a rubber window. They were measured acoustically [4] in the NRL-USRD Lake Facility at a temperature of 28°C and a depth of 4 m. The type of measurements recorded and the measurement results are shown in Table 2.

Table 2 - Acoustic Performance of Copper-Nickel vs. Rubber Window in AT-200 Transducer

Specification	Copper-Nickel Window	Rubber Window
Free-Field Voltage Sensitivity ($\geq$ -175)	-175 dB re 1 V/μPa	-172 dB re 1 V/μPa
Transmitting Voltage Response ($\geq$ +154)	+158 dB re 1 μPa/V/m	+160 dB re 1 μPa/V/m
Sound Pressure Level ($\geq$ +202)	+204 dB re 1 μPa/m	+208 dB re 1 μPa/m

Although there was some acoustic degradation with the copper-nickel window, all measured values were within the published specifications. Therefore, it can be concluded that on the basis of these tests, a copper-nickel window can be substituted for a rubber window without degrading the acoustic performance of the TR-297 transducer below the published specifications.

3. A TR-297 transducer was placed inside an environmental chamber for pressure and window deflection tests as a function of temperature (Fig. 1). The transducer, which had no internal compensator, was filled with castor oil and equipped with a copper-nickel window. The environmental chamber was capable of maintaining any temperature in the range -60 to +75°C. The instrumentation used to measure the significant parameters was applied in the following manner.

The temperature (in degrees Celsius) of the transducer was monitored with a thermistor placed inside the unit and submerged in the castor oil. The pressure internal to the transducer was coupled to a pressure transducer transmitter by plumbing connected to the oil-filler inlet. The pressure was read on a BLH Model 1200A Strain Gage Indicator in units of kPa. The window deflection was measured with a dial micrometer in units of millimeters. The micrometer base was mounted on the framework that was attached to the case of the

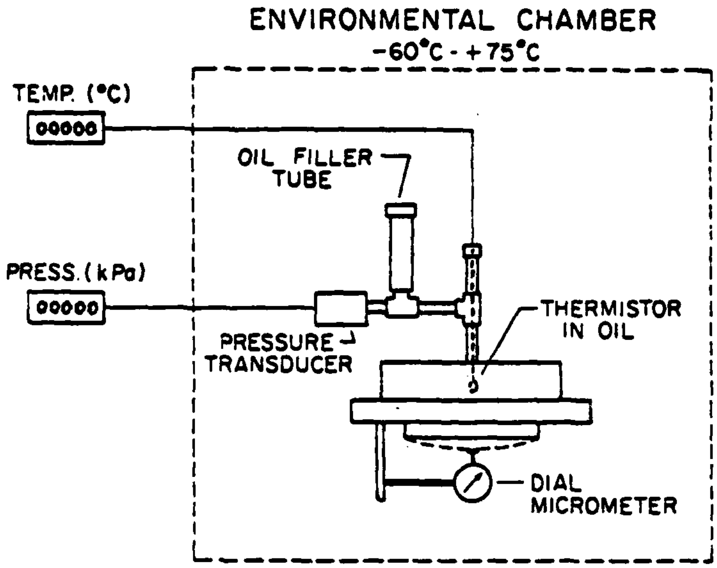

Fig. 1 - TR-297 deflection vs. pressure, funtion of temperature

transducer. The uncertainty of the measurements were:

Internal Temperature	$\pm$0.3°C
Internal Pressure	$\pm$0.3%
Window Deflection	$\pm$0.025 mm.

Prior to test initiation, the temperature of the transducer was 27°C and the pressure was 0 kPa (gage). The temperature was varied three times from -60 to +75°C. The pressure vs. temperature is plotted in Fig. 2. Note that at the rated temperature of +60°C the pressure has risen to 440 kPa (64 psi). It can be seen that the maximum pressure at temperature is directly affected by the location of the atmospheric pressure fill point along the temperature axis. The castor oil should be maintained at +60°C when filling this or any other transducer, providing that this temperature does not damage the internal components; because in addition to keeping the pressure lower at elevated operational temperatures, this practice aids the air-evacuation process. The window deflection vs. pressure is plotted in Fig. 3. At the maximum rated temperature of +60°C and pressure of 440 kPa (64 psi), the window deflection was 1.4 mm (0.056 in.). During the three tests, the window deflection returned to the initial reference point each time.

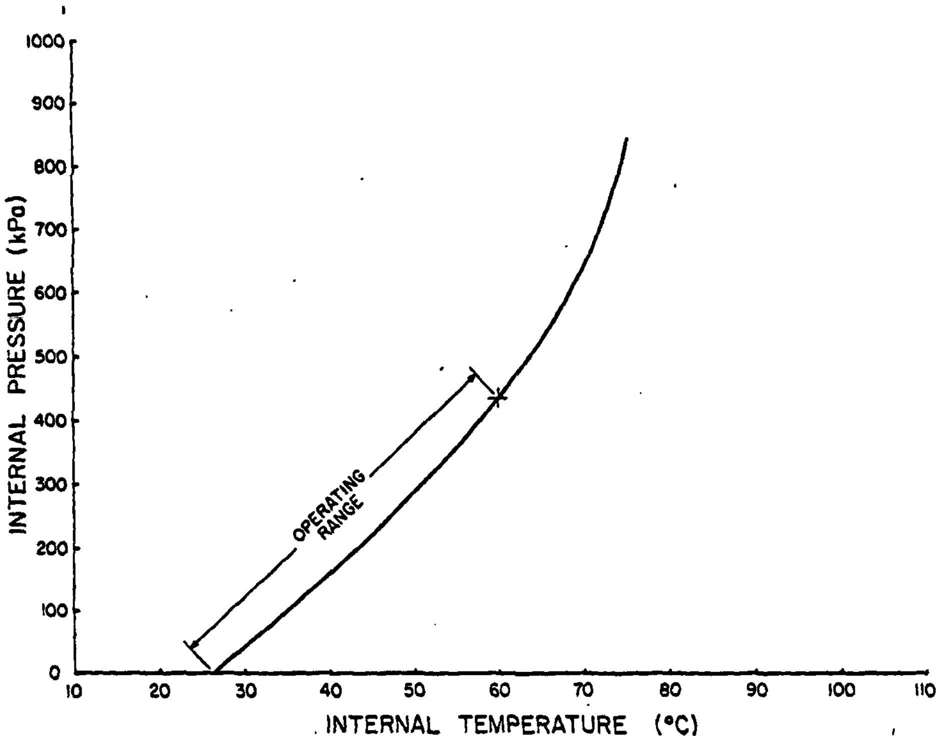

Fig. 2 - TR-297 transducer pressure (kPa) vs. temperature (°C)

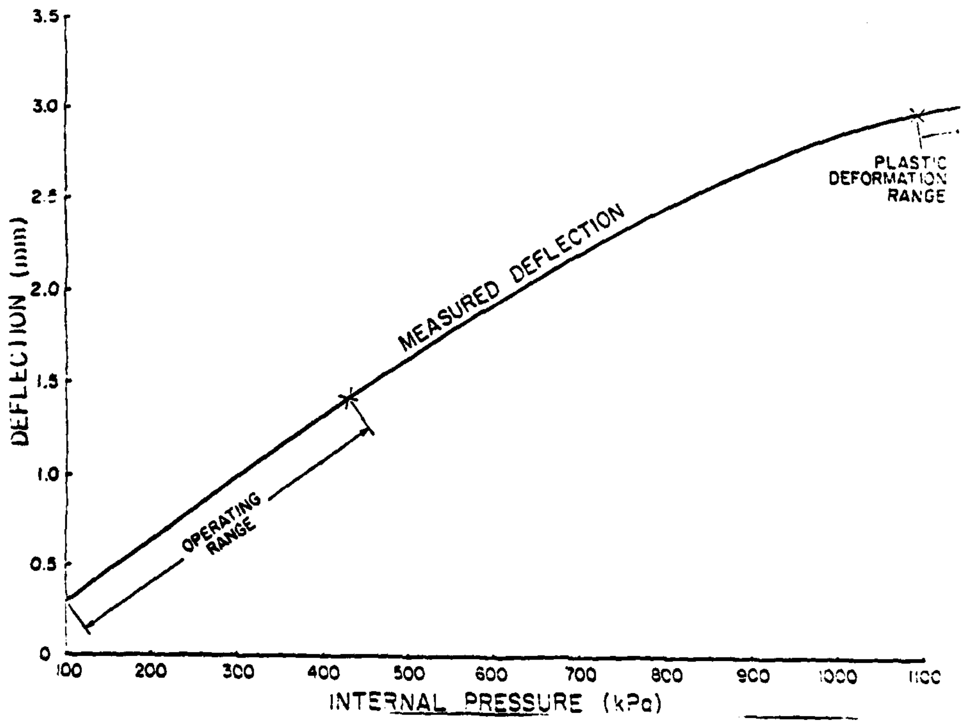

Fig. 3 - TR-297 transducer deflection (mm) vs. pressure (kPa)

The following formula [5] was used to determine the maximum pressure that could be generated inside the transducer without exceeding the stress level that would cause the window to undergo plastic deformation:

$$\text{Pressure to yield} = \frac{\sigma}{0.75} \left(\frac{h}{a}\right)^2$$

Where: σ = yield pressure,

h = thickness, and

a = radius.

This composition of copper-nickel material, uniformly loaded and clamped at the perimeter, has a yield stress of 393 MPa. With a plate thickness of 0.56 cm and a radius of 12.3 cm, the formula yields a plastic deformation pressure limit of 1086 kPa. Beyond this pressure lies the plastic deformation region. Note in Fig. 3 that at the maximum of the operating range the measured deflection extends to only 40% of the elasticity range of the window. Based upon these calculations and data, it appears that the transducer could safely withstand temperatures up to the 75-80°C range.

The maximum total load on the window hold-down bolts at the high temperature (75°C) used during the tests was 40×10^3N (9,000 lbs.). This exerted a 1.1×10^3N (250 lbs.) load on each bolt, which is rated at 8.9×10^3N (2,000 lbs.) [6]. At the maximum rated operating temperature of +60°C, the bolts will be loaded to only 550 N (125 lbs.) each. This is a safety factor of 16. All the seals, gaskets, and components were inspected and showed no visible damage. When the transducer is configured as above, without a pressure compensator, and is serviced and operated within the rated parameters, there should be no problem with the pressure build-up as a function of temperature.

SUMMARY

Tests and evaluation were performed on the following proposed modifications for the TR-297 transducer.

- Castor oil substitution for silicone oil.
- Copper-nickel acoustic window substitution for rubber window.
- Elimination of the internal pressure compensator.

A total of five transducers were used in the testing program. Acoustic measurements were made on two units filled with castor oil and repeated on the same units filled with silicone oil. There were no measurable differences. Two transducers alternately equipped with rubber windows and copper-nickel windows were acoustically measured with an average 3-dB degradation in the copper-nickel window performance, but with all parameters well within the published specifications. An environmental chamber was used for pressure vs. temperature testing of a transducer without an internal pressure compensator. The temperature was cycled three times through the range -60 to +75°C. The internal pressure and window deflection were recorded and found to be well within the limits of the specifications at the rated temperature.

ACKNOWLEDGMENT

Sincere appreciation is extended to Dr. Robert W. Timme of the NRL-USRD for his advice on this project.

REFERENCES

1 - C. E. Green - Performance of Modified TR-297's and AT-200A (Channel Industries, Inc., Santa Barbara, California, Jan 1977).

2 - R. W. Timme - NRL-USRD Code 8275 Program Plan for Sonar Transducer Reliability Improvements (Sep 1977).

3 - R. J. Bobber - Underwater Electroacoustic Measurements (U. S. Govt. Printing Office, Jul 1970).

4 - NRL-USRD Calibration Report 4553 (Oct 1978).

5 - Determination of Yield Strength - ASTM Part 1 (1952).

6 - Standard Handbook of Mechanical Engineers (1976).

APPENDIX - Need for Additional Test Requirements

During the course of this evaluation, several deficient areas in transducer technology were noted. The Compendium of Test Requirements and Operating Characteristics for NAVSEA Sonar Transducers (NAVSEA 0967-LP-410-2020) does not adequately reflect the operational specifications that should be required for this unit. In addition, the manner, methodology, and equipment used in tests and calibration of the sonar devices are not sufficiently standardized. Consideration should be given to testing and verifying the performance of the transducers in the operational environment they will encounter in service. Acoustic tests were made on one TR-297 transducer to evaluate the performance in a changing pressure and temperature environment. Measurements were made[1] in the NRL-USRD Anechoic Tank Facility, and a summary of the data is shown in Table A1.

This unit seems to have two problems of note. The impedance (Z) is too high at 3°C for all pressures. The directivity pattern side lobe level does not meet the specifications of the class "A" transducers which are ≥ 20 dB down from the main lobe level. The specification of class "B" transducer side lobes is ≥ 15 dB down. The unit satisfies these requirements. The directional responses at 22°C and four pressures are shown in Fig. A1. Note the 3-dB and 10-dB down points are practically unchanged while the average change on the side lobes at maximum pressure is 4 dB.

The NUSC-New London Lab developed a scotch-cast pressure-release plate for the AT-200G and conducted tests in the NRL-USRD Anechoic Tank Facility.[2] Figure A2 is a reproduction of the directional response made at 6890 kPa and 4°C. A comparison with the data from the TR-297 suggests that on the basis of one test, this glass-cast material could be superior to that presently used in the TR-297.

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[1] NRL-USRD Calibration Report No. 4604 (Nov 1978).

[2] NRL-USRD Calibration Report No. 4318 (May 1977).

Table A1 - Pressure and Temperature Responses on TR-297 Transducer

Specification	Pressure (kPa)	Temperature 3°C	Temperature 22°C
		Z (ohms) (low-power)	
120-180 Ω	140	222	179
	2070	241	177
	4140	238	179
	6890	236	189
	140	219	179
		Phase (degrees)	
-20 to +20°	140	-18	-20
	2070	-9	-19
	4140	-8	-19
	6890	-8	-14
	140	-17	-19
		SPL (dB)	
≥ 200 dB	140	204	205
	2070	202	204
	4140	202	203
	6890	202	203
		TVR (dB)	
≥ 154 dB	140	158	159
	2070	157	158
	4140	156	158
	6890	156	157
		FFVS (@ 12 kHz)	
≥ -175 dB	140	-171	-171
	2070	-172	-171
	4140	-172	-172
	6890	-173	-172
		Bandwidth (degrees)	
≥ 30° @ 3 dB	140	32	34
	2070	30	36
	4140	32	37
	6890	32	36
	140	32	35
≤ 60° @ 10 dB	140	54	54
	2070	52	57
	4140	42	57
	6890	53	56
	140	54	58
		Sidelobes (degrees)	
≥ 15 dB down	140	15	17
	2070	13	16
	4140	13	15
	6890	14	14
	140	15	16

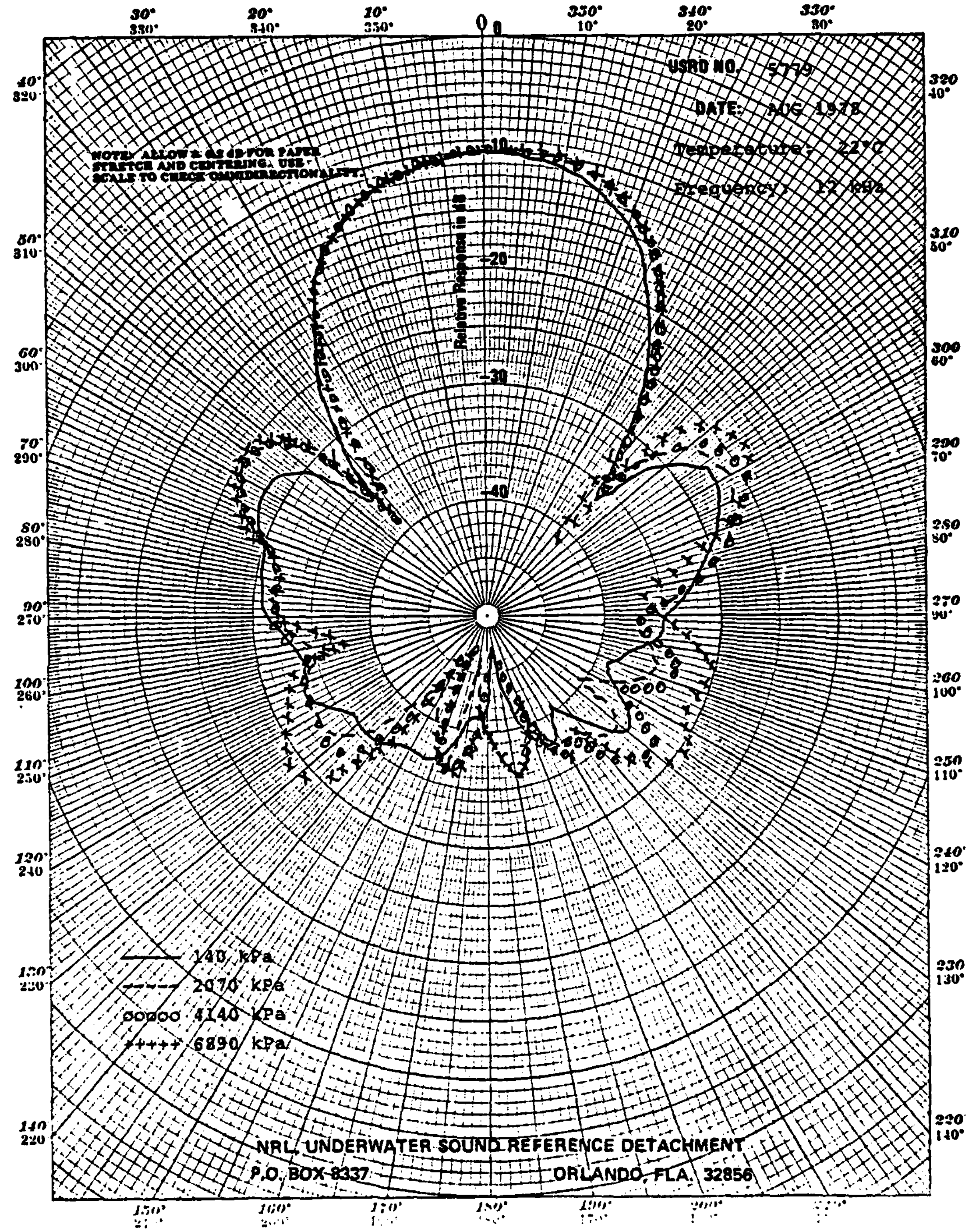

Fig. A1 - Directional responses at 22°C and four pressures

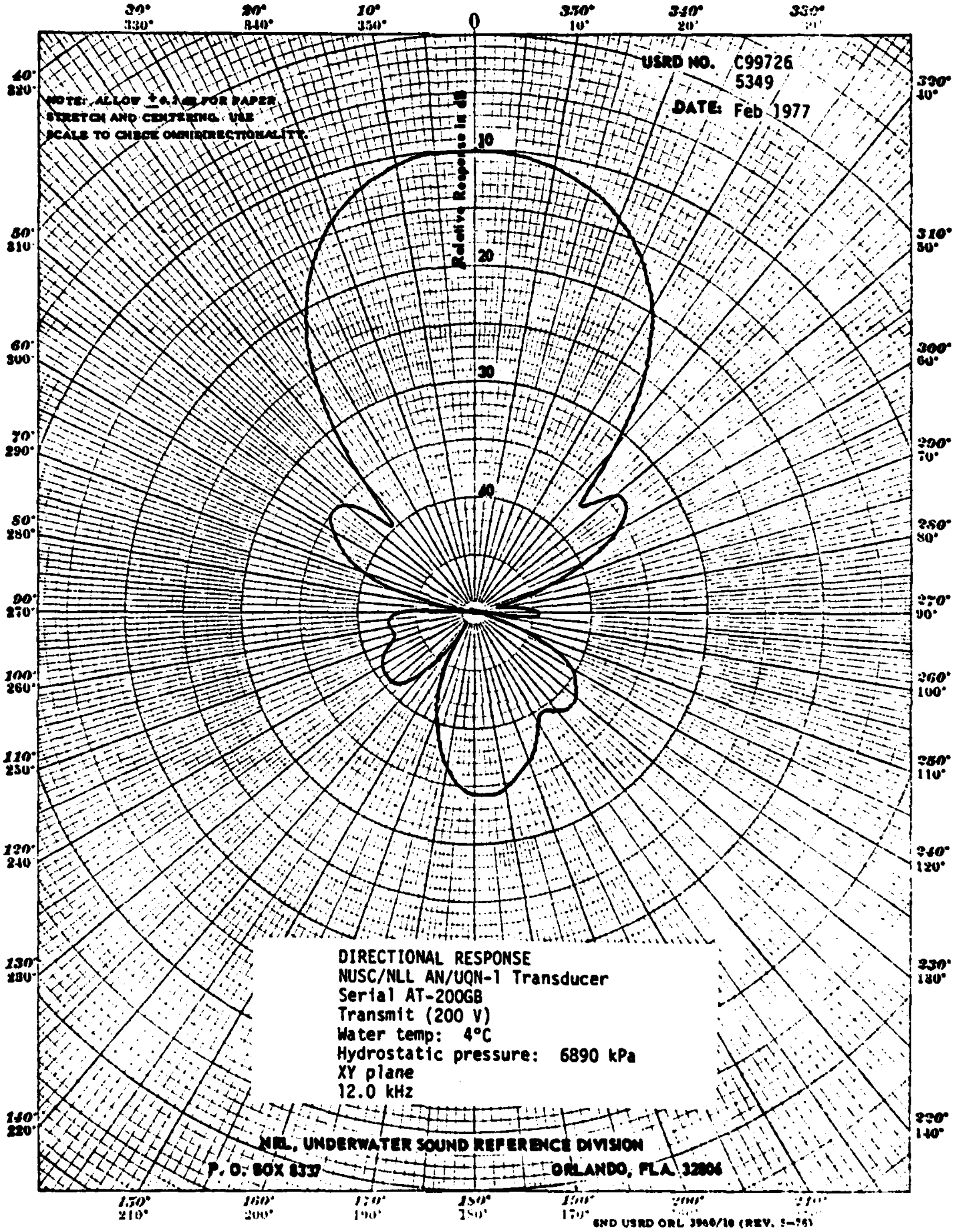

Fig. A2 - Directional response of AT-200G transducer